

Dec. 1875. Prof. Holden, *Drawing of Ring Nebula in Lyra.* 61

In case polar-coordinates  $p$  and  $s$  of the satellites are directly observed, these, or equivalent formulæ, or the kindred ones given in *Astron. Nachrichten*, No. 1040, will be found preferable to those adopted by von Asten and Newcomb, not only on account of their greater simplicity, but still more on account of the far greater facility and directness which they afford for computing the differential coefficients in the equations of condition for correcting the assumed elements.

*Drawing of the Ring Nebula in Lyra* (R.A.  $18^h 48^m 20^s$ : N.P.D.  $57^\circ 8' 57''$  [1860.0]). By Edward S. Holden, Prof. Math. U.S. Navy.

(Communicated by Rear-Admiral C. H. Davis, U.S. Navy, Superintendent U.S. Naval Observatory.)

The original drawing in pastel (of which a photograph on the same scale is sent herewith—viz. 1 inch =  $20''$ ) was constructed from the following measurements taken with the 26-inch Equatoreal of the Naval Observatory, with a magnifying power of about 400 diameters:

1874, June 13. Major axis =  $77''.3$ ; minor axis =  $58''.0$ . Observer, Newcomb. N.B. The distances are only for the brighter portions.

1874, Aug. 10. Rough sketch of the nebula and surrounding stars. S. W. Burnham and Holden.

1875, July 7. Angles of position of four lines from bright star A (brightest in a field of  $6'$ ) tangent to the outer and inner ovals of the luminous ring.

$AB_2 = 239^\circ$ ;  $B_2$  on South side of external oval.

$AB_4 = 248^\circ$ ;  $B_4$  on South side of interior oval.

$AB_3 = 289^\circ$ ;  $B_3$  on North side of interior oval.

$AB_1 = 303^\circ$ ;  $B_1$  on North side of exterior oval.

Differences of Right Ascension between star A and tangents to the *preceding* and *following* sides of both interior and exterior ovals, the differences being measured with the micrometer:

A and  $n_1 = 22''.58$ ;  $n_1$  on *following* edge of exterior oval: ( $n_1$  is not the extreme point, but it is where the nebulosity begins to be definite.)

A and  $n_2 = 36''.31$ ;  $n_2$  on *following* edge of interior oval (in this again there is well-marked nebulosity *preceding*  $n_2$ , that is, inside the interior oval).

A and  $n_3 = 82''.27$ ;  $n_3$  on *preceding* edge of interior oval.

A and  $n_4 = 102''.96$ ;  $n_4$  on *preceding* edge of exterior oval.

A and  $n'_4 = 105''.25$ ;  $n'_4$  on extreme limit of *preceding* nebulosity.

Observer, Holden.

1875, Oct. 24. Position-angle major axis,  $63^{\circ}6$ ; major axis,  $88''\cdot7$  (not to the extreme limit); minor axis =  $60''\cdot1$  (extreme). Sketch made of nebula: bright patches seen, and also star inside the ring. Observer, Holden.

1875, Oct. 25. Angle of position and distance of estimated centre of ring from star A,  $p = 268^{\circ}2$ ;  $s = 61''\cdot6$ .

$$\left. \begin{array}{l} AB_2 = 241^{\circ} \\ AB_1 = 298^{\circ} \end{array} \right\} B_1 \text{ and } B_2 \text{ as on July 7, 1875.}$$

Observer, Holden.

Pencil sketch made, and from all the measures and sketches a pastel drawing made on a scale of 1 inch to  $20''$ . Lassell's and Winlock's drawings compared with the heavens, Oct. 24 and 25.

1875, Oct. 31. Position of major axis =  $63^{\circ}1$ ; of minor axis,  $156^{\circ}8$ .

It is not easy to decide on exact position of minor axis, and the readings are somewhat uncertain. North end of minor axis again seen with several bright points near it. Two bright patches seen. Observer, Holden.

1875, Nov. 2. Position of major axis,  $65^{\circ}5$ ; length,  $89''\cdot5$ ; position of minor axis,  $155^{\circ}8$ ; length,  $66''\cdot5$ . Observer, Hall.

1875, Nov. 6. Position of star A from estimated centre of nebula,  $85^{\circ}6$ ; distance,  $61''\cdot9$ . Observer, Hall.

The drawing represents tolerably well the aspect of this nebula as seen at Washington under average circumstances. The bright patches in the border and the star in the interior are only to be seen in moments of superior definition, but no doubt is entertained as to their existence. The photograph should be held at a distance of about two feet from the eye, in order to represent the apparent size of the nebula as seen in the telescope with a magnifying power of 400 diameters; and at this distance the relative brightness of the stars and the bright patches is properly kept. In the photograph there are one or two bright points in the nebula beside the central star: these are imperfections. The general aspect is, however, better caught at a distance of about ten to fifteen feet, the picture being shaded from direct illumination.

The only published figures of this nebula of which I have any knowledge are:

- I. Herschel's, in *Phil. Trans.*, 1833, plate x. fig. 29.
- II. Rosse's, in *Phil. Trans.*, 1844, plate xix. fig. 29.
- III. D'Arrest's, in *Description of the Copenhagen Equatoreal*, 1861, plate ii. fig. 5; and a good sketch in *Sid. Neb. Obs. Hav.*, p. 334.
- IV. Lassell's, privately distributed, and dated Sept. 19, 1860.
- V. Winlock and Trouvelot's, in *Astronomical Engravings from Harvard College Observatory*, plate xxxiv.

Beside these, there are several rough sketches of Schröeter's

and Harding's in *Beyträge zu den neuesten astronomischen Entdeckungen*, vol. i. plate vi. fig. 27, and vol. iii. plate ii. figs. 5, 6, 7, and 8.

In these Schroeter chronicles the discovery of a small star very close to the ring, and following it exactly in the prolongation of its axis major (according to his first figure), and also the finding of certain bright patches in the ring itself. Schroeter's star does not exist, unless indeed it be the star A of our observations, as D'Arrest supposes (*Sid. Neb. Obs. Hav.*, p. 334). Schroeter's first figure (vol. i.) places the small star very close to the nebulosity, and his description distinctly says, "dicht unten am Rande entdeckte ich einen ausserordentlich kleinen dunkeln kaum erkennbaren Stern." This is certainly not a description of star A, even with Schroeter's telescopic means. His later figures (vol. iii.) probably show our star A. If they do, it is variable, according to Schroeter's evidence given below; if they do not, his star has no existence at present, as it has been specially looked for.

Herschel's drawing (I.) is of very small dimensions and of no detail.

Lord Rosse's (II.) is very *suggestive* of the present appearance, though by no means a representation of the object as it is seen in the 26-inch refractor.

The wisps of nebulosity, extending outward in all directions, are not seen in the latter telescope, and it is a little curious that that end of the minor axis which Lord Rosse has represented as the best terminated, viz. the *south* end, is precisely that one which to-day, and with the Washington telescope, is least so. The difference between the two ends is here not very marked; but still the north end is sharper and brighter as it is described by D'Arrest, *op. cit.* Lassell's drawing (IV.) represents the general aspect of the nebula better than any other. Some of the details which are to be found in Winlock's (V.) are lacking, as, for example, the great diminution of light at the ends of the major axis; but the star in the interior of the ring is shown, and the elliptical shape of the nebula finely given. Winlock's and Trouvelot's (V.) is on a large scale, and is, in general, very similar to the object in the heavens, but I find the three bright spots or patches far too bright to represent their present appearance in the Washington telescope. The *following* end of the major axis appears to be too sharply terminated; the *preceding* end, however, is in excellent agreement with the nebula. D'Arrest's drawing (III.) is not at present accessible to me.

In Lord Rosse's figure, the interior of the ring is represented to be streaked in bands parallel to the major axis, and this appearance has been noted also by Professor C. Abbe with the Cincinnati Equatoreal (12 inches aperture). This does not represent the appearance as seen at Washington, but it suggests it strongly. This appearance it is not attempted to show in my drawing, but it may best be described as a tendency in the light of the interior

oval to an arrangement in streaks parallel to the major axis, and seen principally in the *preceding* half of the ring, and only under the best conditions.

The first detailed notice of bright patches in the ring itself is by Schröter, in the work previously quoted, vol. iii. p. 164, *et seq.* and plate ii. figs. 5-8.

1797, April 16. Harding saw a bright patch ( $\beta$ ), and he gives a rough sketch, from which I deduce the angle of position of the patch to be about  $96^\circ$ , and the distance from the centre about  $\frac{7}{15}$ ths of the diameter. (These figures are quite rough, necessarily.) The small star  $\alpha$  (so-called by Schröter) was seen following the nebula.

1797, Nov. 12. The star  $\alpha$  was at once plainly seen, while of the spot  $\beta$  of April 16 there was not the least trace. It was for the second time remarked that the interior of the ring is filled with faint nebulosity.

1797, Nov. 19. The star  $\alpha$  was again seen. Two sketches were made, one by Harding, and one by Schröter, which agreed in certifying to the existence of two bright spots  $a$  and  $b$ .

$$\begin{array}{ll} a : \text{Pos.-Ang.} = 339^\circ & \text{Dist.} = \frac{5}{15} \text{ths of diameter.} \\ b : \quad \quad \quad = 17^\circ & \quad \quad \quad = \frac{5}{15} \text{ths of diameter.} \end{array}$$

Their light was *notably* brighter than that of the rest of the nebula, and somewhat twinkling at times. The *preceding* and *following* sides of the nebula were then observed to be, as they are now, somewhat fainter than the rest.

1798, Oct. 27. The *preceding* or *western* side of the ring was seen much darker than the rest, so that the ring looked divided or broken at this point; but on the *following* side this was not the case, as on Nov. 19, 1797.

Again, both the bright spots  $a$  and  $b$  of that date had disappeared; and in a position-angle of  $13^\circ$ , distance about  $\frac{6}{15}$ ths, a bright spot  $c$  was noticed. This could not be the spot  $b$  of Nov. 19, since it was much nearer the edge of the ring.

1798, Dec. 20. The interior of the ring was bright greyish like the sky illuminated by moonlight, and the *western* (*preceding*) and outer portion of the ring itself was not half so bright as the rest of the ring, and as its following border, which, on the 19th of November 1797 had been found equally dark. No bright patches were seen in any part of the ring itself. The star  $\alpha$ , which had been seen with difficulty on dark nights, was now plainly visible to both observers in bright moonlight.

Sir William Herschel has a few remarks upon this nebula in Bode's *Jahrbuch* 1788, p. 242. He speaks of it as apparently a ring of stars with a regular and concentric dark spot or space in the midst. "Er ist von ovaler Figur, seine kleine Axe verhält sich zur grössern wie 83: 100. . . . Das Licht desselben ist von der auflösbaren Gattung und an der nordl. Seite kann man 3 sehr schwache Sterne erkennen, sowie einen oder zwei am



südlichen Theil. Die Ende der längern Axe scheinen weniger  
 gänzend und nicht so deutlich abgeschnitten als die übrige. .  
 . . siehe Fig. 9" [Fig. 9 is a simple sketch of no detail]. Von  
 Hahn in the *Jahrbuch* for 1803, p. 106, has some further observa-  
 tions with a 20-foot reflector. "Ich finde in dem berühmten  
 Sternring . . merkliche Veränderungen. Vor einigen Jahren  
 war das innre Ring so klar, dass ich . . . in dessen Mitte  
 ein teleskopisches Sternchen unterscheiden konnte. Jetzt zeigen  
 sich . . . schwache feine Wolken und der kleine Stern  
 ist gar nicht sichtbar. Eine Veränderung ist sicher vorgefallen.  
 Es kann aber auch sein, dass der Ring sein Stelle verändert hat,  
 und nur auf dem unendlich viel weiter als der Ring entfernten  
 Himmelsgrunde, der durchsichtige Ring anders erscheint."

From Sir John Herschel's "Observations of Nebulae, &c.," in  
*Phil. Trans.* 1833, p. 462, I extract a few notes regarding this  
 nebula: "Position of longer axis of annulus  $57^{\circ}0$  by micro-  
 meter . . . diameter in R.A.  $5^{\text{s}}375$  by a mean of four careful  
 observations. The Star following it is  $11^{\text{m}}$ . It follows the  
 centre  $4^{\text{s}}31$ , and its position from centre is  $96^{\circ}4$  by micro-  
 meter. The nebula has a mottled look. [N.B. This mottled  
 look, however, is something quite different from the appearance  
 called resolvable.]"

D'Arrest speaks of it as follows in his *Sid. Neb. Obs. Hav.*,  
 p. 334: "Adspectu floccosa —  $*14^{\text{m}}$  (non  $11^{\text{m}}$ ) seq. in  
 parallelo,  $*14^{\text{m}}$  in seq. centrum accurate in parallelo  $4^{\text{s}}67$ .  
 Margo borealis australi certe lucidior: in ipsa neb. 2 vel 3 fixæ  
 subtilissimæ conspiciuntur. . . . In limbo boreali eoque certe  
 lucidiore duæ stellulæ satis distincte affulgent; nulla vero intus  
 in annulo." Angul. posit. axis majoris =  $58^{\circ}43'$ . Axis  
 major =  $58^{\circ}1$ ; axis minor =  $59''9$ .

Secchi (*Ast. Nach.* bd. 43, col. 160) saw, "très bien dans  
 l'intérieur une très petite étoile un peu au-dessous (apparent)  
 (that is, north) de son centre."

Auwers in *Ast. Nach.* bd. 58, col. 375, has the following obser-  
 vations (1862): "Grosse Axe des äussern Ringrandes =  $75''0$   
 in Pos.  $70^{\circ}0$  Klein =  $61''5$  (2 Tage). . . . Stern  $11^{\text{m}}6$   
 $d = 61''1$ ,  $p = 87^{\circ}1$  (2 Tage): daraus folge  $\Delta \alpha = 4^{\text{s}}84''$ ."

Dr. H. Schultz, in his recently published "Observations of  
 500 Nebulae" (Upsala, 1874), has the following notes on this  
 nebula:—

"1865, August 12. Nebula bluish and strongly granulate;  
 north part brighter. Position of the major axis  $57^{\circ}9$ ; minor  
 axis,  $148^{\circ}9$ . . . .

"1865, August 13. The north part of the ring brightest;  
 strongly granulate, with several not very faint stars seen  
 by momentary glimpses: 2 or 3 stars in the *north-preceding*  
 part and 2 in the *south-following* part of the ring dis-  
 tinctly seen; at the interior margin of the ring 2 stars  
 visible in the *south-preceding*, and one in the *south-following*  
 part. Hahn's star a little *north-preceding* the geometrical

centre, momentarily visible ; dull and planetary. All these stars only so momentarily seen that to adjust the micrometer wire upon them was quite impossible. The *north-following* part of the ring very diffuse with nebulous radiations in the direction of the longer axis, which seem momentarily almost to destroy the annular form. The central vacuity not inconsiderably nebulous. . . . .

" 1867, August 6. Hahn's central star distinctly seen without effort . . . the *north-following* end only momentarily well defined.

" 1870, August 8. . . . Twinkling stellar points at the *north* outer margin, which is best defined." . . .

Lamont's observations of 1838-9, with a sketch, are given in *Annalen d. k. Stv. bei München*, bd. xvii.

My own notes on the bright patches are as follows. They refer specially to 1875, October 24-25 :—

"Minor axis more sharply terminated on *north* side: near *north* end of minor axis is a bright patch. The star inside the ring is seen occasionally: it is very near the *south-preceding* corner of a square formed by three stars outside (which are Lassell's Nos. 1, 8, and 5 or 6) and itself. The whole of the interior glistening in points. At the *south* end of the minor axis filaments of nebulosity extend 15" to 30" off. These are very faint. The *following* end of major axis is better terminated than the *preceding*. Two brighter spots are seen in the *north-preceding* and *south-following* parts of the ring, and possibly a third in *south-preceding* part. At both ends of the minor axis are several which cannot be located exactly."

With regard to the identity of the star 14<sup>m</sup> = Lassell No. 1 with Schroeter's star *a*, I find from Schroeter's first drawing that its distance from the *following* end of the major axis was not more than 4" or 5". His subsequent drawings certainly represent our star 14<sup>m</sup>; and he refers to this 14<sup>m</sup> as if it were the one first seen by himself and Harding on 1786, November 13.

The question is of no great importance, except as to the existence of a small star so close to the ring. As I have said, this star has been looked for, and at present does not exist.

I add a Table containing measures of this nebula, for convenience of reference :—

Date.	Angle of Position.	Distance.	Authority.
<i>Major Axis.</i>			
	°		
1825-33	57°0	5".375 (diam. in R.A.)	Herschel.
1837-9	66 22' (mean of two varying 8°)	68".4 (Major Axis, m.m.)*	Lamont.
1860	...	89" ( " " " )	Lassell.
1863	58 43'	78".1 ( " " " )	D'Arrest.

\* In the table, m. stands for *measures*, and m.m. for *micrometer measures*.

centre, momentarily visible ; dull and planetary. All these stars only so momentarily seen that to adjust the micrometer wire upon them was quite impossible. The *north-following* part of the ring very diffuse with nebulous radiations in the direction of the longer axis, which seem momentarily almost to destroy the annular form. The central vacuity not inconsiderably nebulous. . . . .

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1863	58 43'	78".1 ( " " " )	D'Arrest.

\* In the table, m. stands for *measures*, and m.m. for *micrometer measures*.

Date	Angle of Position.	Distance.	Authority.
1863	58°43'	5".66 (diam. in R.A.)	D'Arrest.
	...	5".30 ( " " )	"
1863	70°0 (query 60°0??)	75".0 (Major Axis, heliometer)	Auwers.
1865-6	57°9	59".7 (diam. in R.A.)	Schultz.
1874	...	77".3 (Maj. Axis, not extreme, m.m.)	Newcomb.
1875	63°6	80".4 (diam. in R.A., m.m.)	Holden.
"	63°1	88".7 (Major Axis, m.m.)	"
"	65°5	89".5 ( " " " )	Hall.

*Minor Axis.*

1860	...	68" (Minor Axis, m.m.)	Lassell.
1837-9	...	55".4 ( " " " )	Lamont.
1863	...	59".9 ( " " " )	D'Arrest.
"	...	61".5 ( " " heliometer)	Auwers.
1865-6	148°9	58".1 (diam. in $\delta$ , m.m.)	Schultz.
"	...	58".8 ( " " " )	"
"	...	56".5 ( " " " )	"
"	...	56".1 ( " " " )	"
1874	...	58".0 (Minor Axis, m.m.)	Newcomb.
1875	156°8	60".1 ( " " " )	Holden.
"	155°8	66".5 ( " " " )	Hall.

*Star 14<sup>m</sup> = Lassell No. 1.*

1825-33	96.4	$\Delta$ R.A. = 4 <sup>s</sup> .31	Herschel.
1837-9	88 22'	... ..	Lamont.
1863	" in seq. centrum accurate in	$\Delta$ R.A. = 5 <sup>s</sup> .47	D'Arrest.
"	parallelo . . 90°	$\Delta$ R.A. = 4 <sup>s</sup> .67	"
"	87°.1	} 61".1 (dist., heliometer)	Auwers.
"	...		
1865-6	86.8 (computed from m. of $\Delta\delta$ )	$\Delta$ R.A. = 5 <sup>s</sup> .22	Schultz.
"	...	$\Delta$ R.A. = 4 <sup>s</sup> .86	"
1875	...	$\Delta$ R.A. = 62".8 (m.m.)	Holden.
"	...	= 4 <sup>s</sup> .99 (computed from above)	"
	88.2	61".6 (distance m.m.)	"
"	85.6	61".9 ( " " )	Hall.



In this table I remark the following differences;—

1st, Position of major axis :

	<sup>0</sup>	
Holden—Herschel	= +6.4	1825-33
„ —Lamont	= -3.0	1837-9
„ —D'Arrest	= +4.7	1863
„ —Auwers	= -6.6	1863 (query +3°4??)
„ —Schultz	= +5.5	1865-6
„ —Hall	= -1.1	1875

2nd, Length of major axis :

The measures are so discrepant that a comparison will be of no particular value except between instruments of the same class.

3rd, Position of minor axis :

	<sup>0</sup>	
Holden—Schultz	= +7.9	1865-6
„ —Hall	= +1.0	1875

4th, Length of minor axis :

	<sup>0</sup>	
Holden—Lamont	= +4.7	1837-9
„ —Lassell	= -7.9	1860
„ —D'Arrest	= +0.2	1863
„ —Auwers	= -0.4	1863
„ —Newcomb	= +2.1	1874
„ —Hall	= -6.4	1875

5th, Position of Star 14<sup>m</sup> = Lassell No. 1 :

	<sup>0</sup>	
Holden—Herschel	= -8.2	1825-33
„ —Lamont	= -0.2	1837-9
„ —D'Arrest	= -1.8	1863
„ —Auwers	= +1.1	1863
„ —Schultz	= +1.4	1865-6
„ —Hall	= +2.6	1875

6th, Distance of Star 14<sup>m</sup> from estimated centre of nebula :

	<sup>0</sup>	
Holden—Auwers	= +0.5	1863
„ —Hall	= -0.3	1875